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Student Notes
Science on Saturday
Lawrence Livermore National Laboratory

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Las Banos High School

Biodefense Detection to Protect the Nation

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DESCRIPTION
Biodefense is a new component of national security, dedicated to protecting the country and the people against infectious disease and harmful biological agents. Since germs can grow and multiply in a host body and then spread to other people – even a small quantity of a deadly pathogen could be used to infect tens, thousands, or possibly *millions* of individuals. Infectious diseases continue to plague to modern society. Scientists are working to understand the mechanism of infectious disease. Engineers are building new tools and instruments to detect, prevent, and/or eliminate infectious disease. Doctors and health-care providers are using these new technologies in their practice, and alert us to new diseases which may be emerging.

Goal: To understand new methods being developed to detect germs before they can cause an epidemic outbreak of potentially deadly infectious disease.

QUESTIONS

1. What is biodefense..?

2. Match the terms in the left column to the correct phrase on the right:

_____ virus	**a**. discovered the "germ theory" of infectious disease
_____ antibody	**b**. the body's own defense against germs
_____ Louis Pasteur	**c.** any agent which can trigger an immune response
_____ fluorescence	**d.** requires a host cell to multiply

_____ antibiotic **e.** light which is produced from other light energy

_____ Edward Jenner **f.** any agent which can cause an infectious disease

_____ immune system **g.** tried to infect an innocent child with smallpox

_____ pathogen **h.** a protein molecule that can bind to a specific germ

_____ antigen **i.** medicine which can stop or kill a bacterial infection

3. True or False..?

- Infectious disease can kill more people than a nuclear bomb. **T / F**
- We don't need to worry about future epidemics, because we have vaccines. **T / F**
- Our skin is an important defense mechanism against infectious disease. **T / F**
- A healthy person has up to 1000 different antibodies in their bloodstream. **T / F**
- Immunoassays are used to detect germs faster than by using lab cultures. **T / F**

4. Fill in the blanks: *P __ __ V __ NT __ __ N is the best DEFENSE..!*

5. Would you rather be a <u>scientist</u>, <u>engineer</u>, or <u>physician</u> – and why?

This lecture supports the California Content Standards Grades 9-12

Physics

4. Waves have characteristic properties that do not depend on the type of wave. As a basis for understanding this concept:
   a. Students know waves carry energy from one place to another.

Cell Biology

1. The fundamental life processes of plants and animals depend on a variety of chemical reactions that occur in specialized areas of the organism's cells. As a basis for understanding this concept:
   c. Students know how prokaryotic cells, eukaryotic cells (including those from plants and animals), and viruses differ in complexity and general structure.

5. The genetic composition of cells can be altered by incorporation of exogenous DNA into the cells. As a basis for understanding this concept:
   c. Students know how genetic engineering (biotechnology) is used to produce novel biomedical and agricultural products.

Physiology

10. Organisms have a variety of mechanisms to combat disease. As a basis for understanding the human immune response:
   a. Students know the role of the skin in providing nonspecific defenses against infection.
   b. Students know the role of antibodies in the body's response to infection.
   c. Students know how vaccination protects an individual from infectious diseases.
   d. Students know there are important differences between bacteria and viruses with respect to their requirements for growth and replication, the body's primary defenses against bacterial and viral infections, and effective treatments of these infections.

Investigation and Experimentation

1. Scientific progress is made by asking meaningful questions and conducting careful investigations.

<u>PHYSICS</u>

Conservation of Energy and Momentum

2. The laws of conservation of energy and momentum provide a way to predict and describe the movement of objects. As a basis for understanding this concept:
   c. *Students know* how to solve problems involving conservation of energy in simple systems, such as falling objects
   h. Students know how to solve problems involving conservation of energy in simple systems with various sources of potential energy, such as capacitors and springs.

Heat and Thermodynamics

3. Energy cannot be created or destroyed, although in many processes energy is transferred to the environment as heat. As a basis for understanding this concept:
   a. Students know heat flow and work are two forms of energy transfer between systems.

Waves

4. Waves have characteristic properties that do not depend on the type of wave. As a basis for understanding this concept:
   a. Students know waves carry energy from one place to another.
   c. Students know how to solve problems involving wavelength, frequency, and wave speed.
   e. Students know radio waves, light, and X-rays are different wavelength bands in the spectrum of electromagnetic waves, whose speed in a vacuum is approximately 3×10^8 m/s (or 186,000 miles/second).
   f. Students know how to identify the characteristic properties of waves: interference (beats), diffraction, refraction, Doppler effect, and polarization.

CHEMISTRY

Atomic and Molecular Structure

1. The periodic table displays the elements in increasing atomic number and shows how periodicity of the physical and chemical properties of the elements relates to atomic structure. As a basis for understanding this concept:
   j. Students know that spectral lines are the result of transitions of electrons between energy levels and that these lines correspond to photons with a frequency related to the energy spacing between levels by using Planck's relationship ($E = hv$).

Chemical Bonds

2. Biological, chemical, and physical properties of matter result from the ability of atoms to form bonds from electrostatic forces between electrons and protons and between atoms and molecules. As a basis for understanding this concept:
   a. Students know atoms combine to form molecules by sharing electrons to form covalent or metallic bonds or by exchanging electrons to form ionic bonds.
   b. Students know chemical bonds between atoms in molecules such as H_2, CH_4, NH_3, H_2, CCH_2, N_2, Cl_2, and many large biological molecules are covalent.

Organic Chemistry and Biochemistry

10. The bonding characteristics of carbon allow the formation of many different organic molecules of varied sizes, shapes, and chemical properties and provide the biochemical basis of life. As a basis for understanding this concept:
    a. Students know large molecules (polymers), such as proteins, nucleic acids, and starch, are formed by repetitive combinations of simple subunits.

BIOLOGY/LIFE SCIENCES

Cell Biology

1. The fundamental life processes of plants and animals depend on a variety of chemical reactions that occur in specialized areas of the organism's cells. As a basis for understanding this concept:
   a. Students know cells are enclosed within semipermeable membranes that regulate their interaction with their surroundings.
   b. Students know enzymes are proteins that catalyze biochemical reactions without altering the reaction equilibrium and the activities of enzymes depend on the temperature, ionic conditions, and the pH of the surroundings.
   c. Students know how prokaryotic cells, eukaryotic cells (including those from plants and animals), and viruses differ in complexity and general structure.
   h. Students know most macromolecules (polysaccharides, nucleic acids, proteins, lipids) in cells and organisms are synthesized from a small collection of simple precursors.

Physiology

10. Organisms have a variety of mechanisms to combat disease. As a basis for understanding the human immune response:
    a. Students know the role of the skin in providing nonspecific defenses against infection.
    b. Students know the role of antibodies in the body's response to infection.
    c. Students know how vaccination protects an individual from infectious diseases.
    d. Students know there are important differences between bacteria and viruses with respect to their requirements for growth and replication, the body's primary defenses against bacterial and viral infections, and effective treatments of these infections.
    e. Students know why an individual with a compromised immune system (for example, a person with AIDS) may be unable to fight off and survive infections by microorganisms that are usually benign.
    f. *Students know the roles of phagocytes, B-lymphocytes, and T-lymphocytes in the immune system.

INVESTIGATION & EXPERIMENTATION

1. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other four strands, students should develop their own questions and perform investigations. Students will:
   a. Select and use appropriate tools and technology (such as computer-linked probes, spreadsheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.
   d. Formulate explanations by using logic and evidence.
   e. Recognize the cumulative nature of scientific evidence.
   l. Analyze situations and solve problems that require combining and applying concepts from more than one area of science.
   m. Investigate a science-based societal issue by researching the literature, analyzing data, and communicating the findings. Examples of issues include irradiation of food, cloning of animals by somatic cell nuclear transfer, choice of energy sources, and land and water use decisions in California.

Associate Director for Science and Education Integration at the NSF Center for Biophotonics, Science and Technology

Frank Y. S. Chuang, M.D., Ph.D. received his undergraduate degree in bioengineering at UC Berkeley in 1987. Frank joined a team at Lawrence Berkeley National Laboratory (LBNL) to develop one of the first systems to treat surgically-inoperable brain tumors using accelerated heavy charged-particle beams. This work became part of the clinical neurosurgery programs at UCSF and Stanford University, and led to the eventual construction of the dedicated medical proton accelerator facility at Loma Linda Medical Center. In 1990, Frank received an NIH fellowship to join the Medical Scientist Training Program (MSTP) at the Mount Sinai School of Medicine in New York. His graduate research using fluorescence microscopy and spectroscopy to characterize the transmembrane signal activation of human white blood cells contributed to the current body of evidence which supports the existence of lipid “rafts” and microdomains in biomembrane architecture and physiology. After completing his medical training and receiving a Ph.D. in immunology and biophysics, Dr. Chuang returned to California as a post-doctoral research fellow at the Lawrence Livermore National Laboratory (LLNL). In the Division of Medical Physics and Biophysics (M-Division, formerly the Medical Technology Program), he was the lead biomedical scientist for several projects developing new in vitro diagnostic systems for rapid, multiplex detection of microbial pathogens, and has written numerous papers and book chapters on optical methods of biodetection. Dr. Chuang's current role in CBST is to provide integrative scientific, technical, and administrative support for the senior management team - and to serve as a biomedical research consultant for the science and educational programs. Dr. Chuang also works in part for the LLNL-UC Davis Integrated Cancer Center and is leading the effort on a joint project to develop clinical applications for a revolutionary new compact proton accelerator being designed and built in Livermore.